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# The effect of Handover Quality on Buffering Requirements in WATM

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WATM, Handoff, Buffering, Capacity, B-ISDN

## Abstract

*In order to maintain Quality of Service (QoS) guarantees during a wireless ATM handover, the cell stream must be buffered while a new connection is established. Once handoff is complete the buffers can be emptied and normal transmission resumes. This prevents cell loss but can introduce cell delay variation (CDV) which is detrimental to real time and delay sensitive services. Additional flow control buffers can overcome this; however, the quality of the handoff will greatly affect the loading on these buffers. In this paper a lossless handover method is analysed using the Opnet simulation tool, varying qualities of handoff are modelled and the buffer loading is measured. Practical data gathered using a 5GHz variable rate modem is included in the model to provide radio performance characteristics and allow cell retransmission rates and other factors that will affect the handover to be incorporated. The results from the Opnet simulation are presented including cell delay and delay variation, utilisation and loading of buffers and handover efficiency.*

## 1 Introduction

With mobile phones starting to offer limited access to the World Wide Web, the demand for connection to B-ISDN core networks will now increase rapidly in all areas of wireless bearer delivery. Systems such as UMTS and IMT 2000 will provide greater bandwidths and a wider range of services but cannot meet all future demands. Wireless ATM is regarded as the logical extension to existing ATM systems and can provide seamless user access to the B-ISDN core network. It supports a wide range of services including real time data streams and bursty traffic as well as multimedia applications. To achieve this, WATM must provide and maintain QoS guarantees to portable and mobile terminals, this will

involve location management and more importantly connection handover as users move from one radio access point to another. In order to provide the higher capacities needed to support ATM data rates WATM networks are likely to use a micro or pico cellular layout that will lead to a greater frequency of connection handover. This along with the varied QoS requirements of different services mean connection handoff is more complex, [1] particularly for services requiring low loss or low delay. To ensure the QoS parameters of these connections are maintained a 'cushioned handoff' can be used, this involves buffering the data stream while the call is switched to the new radio access point. The disadvantage of this method is that delay and delay variations occur and so a certain amount of flow control buffering is needed at the receiver. The ideal situation in which a handoff occurs is when the need for reconnection to a new radio access system (RAS) can be predicted ahead of time. This allows the handover signalling to be carried out through the old RAS and means the minimum amount of disruption is caused to the connection as the new wireless link can be set up ready for the ATM connections. This method is known as a seamless, backward handover. The less desirable alternative is a forward handoff when the original link fails and all signalling must be performed through the new RAS. When a handoff is carried out the backbone ATM network must switch all virtual connections (VCs) to and from the mobile through the new RAS. If the new RAS is connected to the same switch as the original access point, connection re-routing only requires the output port of the ATM switch to be changed, an intra switch handover. In the case of the new RAS being connected to a different ATM switch a common connection point must be established between the two switches. This is known as the Anchor Switch and is the point at which the connection is transferred to the new switch and RAS, this is called an inter-switch handover but will not be dealt with in this paper. It is important that handover architectures are robust and flexible enough to function in any of these situations.

When a backward handover occurs it is likely to mean the system has detected a new base station and the present link performance is deteriorating to below the level specified by the ATM connections being carried on the link. In a WATM system the quality of the handoff will be affected by a number of factors. These include; the time taken for the handover to complete starting when the old link is suspended until transmission begins to the new RAS. The type of ATM connection as some may require cells to be forwarded onto the new RAS for transmission if they had been queued at the old base station. Finally the available capacity at the new radio access point will affect the speed with which the buffers can be cleared and whether the present level of service can be continued. This paper is primarily concerned with the performance of a constant bit rate connection (CBR) such as video stream, being handed off using a backward handover scheme with varying constraints on the handover.

### 1.1 WATM System Architecture

A WATM system consists of three main parts [2], the core ATM network made up of standard ATM switches, a mobility enhanced ATM switch and a RAS. The RAS is made up of a base station (BS) and mobile terminals (MT). The simulation results presented were obtained using the Opnet modelling tool; a simple indoor network was created with a mobility enhanced ATM switch, two base stations and a mobile terminal moving between them [Figure1-1]. Bi-directional traffic was generated between the MT and core network using a CBR source at either end of the connection.

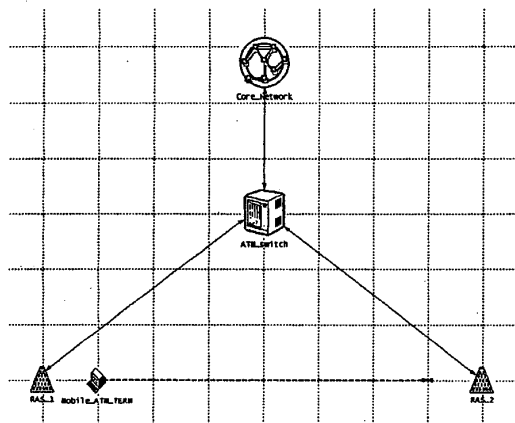


Figure1-1 The WATM handover model on Opnet

The Opnet models were designed including traffic generation, processing and queuing modules an example of which can be seen in Figure 1-2. The radio parts were taken from the tool bar and customized to match the performance of the intended wireless link.

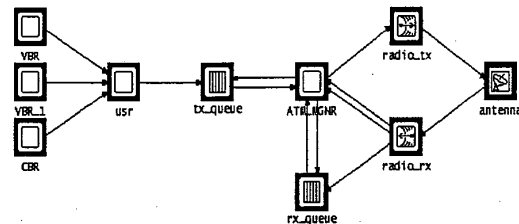


Figure 1-2 Opnet node showing queues and traffic generation modules

The simulation model was augmented with real data gathered using a 5GHz, variable rate, QPSK modem [3]. The transmission rate was set to 26 Mbit/s and data was collected from a number of locations within the Queens Building at the University of Bristol. In the case of Figure 1-3 a line of sight path was used through the main electrical laboratory with a transmit power of 5dBm. The data was collected over 127 bit samples giving actual errors and allowing approximate bit error rates to be calculated. These were added to the Opnet model by including an additional transmitter to interfere with the connection. The robustness of radio link could then be specified at the receiver thus allowing cell loss rates to be measured and retransmission rates included in node models.

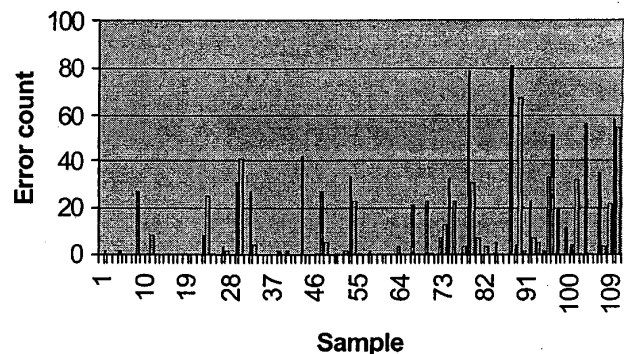


Figure 1-3 Error counts for QPSK modem

The handover mechanism used for this simulation utilised a mobile-controlled backward handoff [4,5] and is shown in Figure 1-4. This method allows for a very fast reaction time ( $\sim 0.1s$ ) to any degradation of the channel, this is important when minimal loss and delay is required and reduces the size of the queues generated. It also reduces the bandwidth overhead needed to empty the buffers.

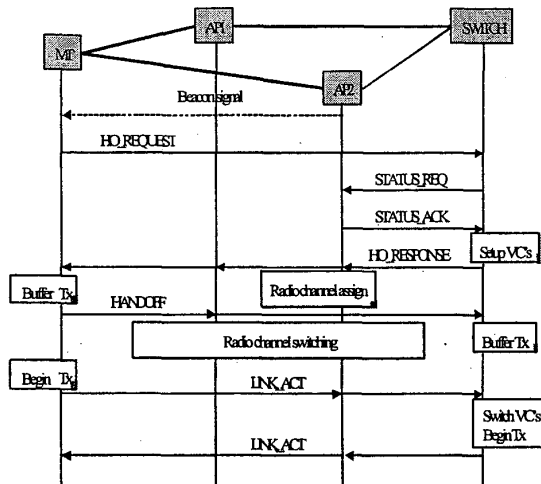


Figure 1-4 Backwards handover flow chart

The MT monitors signals from other base stations and if the link quality at another access point (AP) is better than the present link, a handover may be requested. The handover request will contain details on the number and type of connections to be handed off and the identity of the new AP. The new base station is interrogated to assess whether there are sufficient resources available to accommodate the new connections without dropping/failing the on-going services. If the handoff can be supported a response is sent to the MT and the radio channels are assigned at the new access point. The MT can now handover to the new base station at any time but to reduce disruption to the ATM connections this will be left until the quality of the present link has begun to approach the QoS threshold specified in the service contract. The MT then begins buffering the cell stream and sends a handoff signal before switching to the new radio channels, releasing the old link. When the ATM switch receives the handoff message it also starts buffering the cell stream, it then waits until it receives a link activation from the new base station before switching though the Virtual Connections (VCs) and starting transmission. All old connections are now released and the handoff is complete. This architecture can be used for a forward handoff [6] with minor

signalling adjustments and would also support network handovers.

## 2 Simulation

The radio interface used in the simulation was set to match that of the 5GHz modem used to gather the practical results. This had a transmission rate set at 26 Mbit/s and a transmit power output of 5 dBm. The antenna patterns were set to be omni-directional like the ones used in the practical measurements and the MT was set to follow a path between the two RAS moving at 1m/s. Radio links proposed for various WATM demonstrators utilise a dynamic TDMA/TDD air interface similar to those in [7]. In this case the simulation used FDD for ease of implementation and a 50% radio related coding and protocol overhead was assumed [8]. This gave an effective link capacity of 6.5 Mbit/s. The traffic source used was a CBR generator with a bit rate of 373kbps equivalent to a low rate video stream.

The simulation was run a number of times each time with a different handover delay. While handover was taking place the cell streams were buffered. The amount of additional bandwidth available in the new radio cell was also varied for each of these simulation runs. Any cells waiting for retransmission when handover occurred were forwarded to the new base station at the head of the cell queue.

### 2.1 Results

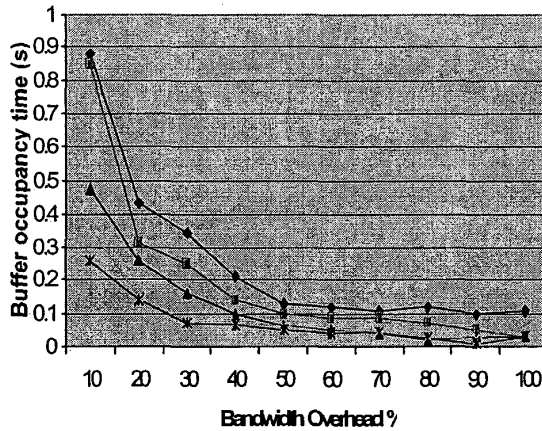
The queue sizes generated for different handover delays can be seen in Table 2.1 and as would be expected are directly proportional to the handover delay.

Handover Delay / ms	Mean Queue Size Generated / cells
25	46
50	67
75	88
100	111
125	136

Table 2.1 Queue sizes for different handover delays

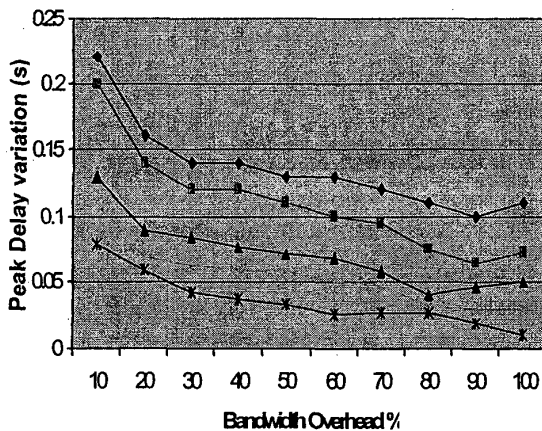
The time taken to purge the buffers after handover was also measured. This would be affected by the amount of traffic in the new radio cell. For ease of measurement the Medium Access Control was adjusted to make varying degrees of additional bandwidth available to the

connection. The greater the available bandwidth in the new RAS the faster the buffers can be emptied. However, from the graph it appears that buffer occupancy time increases significantly when there is less than 20% of additional bandwidth. If higher data rates are transmitted the curve follows the same trend but buffer sizes and occupancy times are increased.



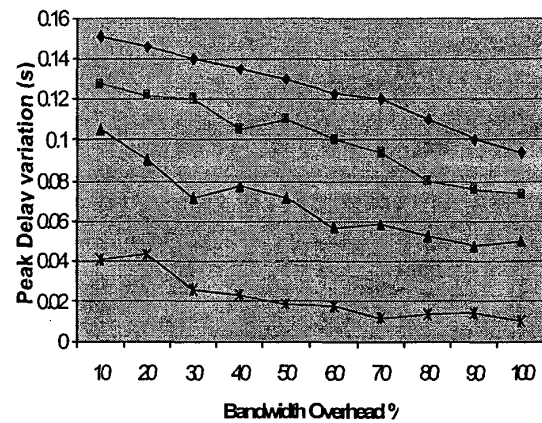
**Figure 2-1 Buffer occupancy time after handover for 125ms down to 25ms switching delay**

The peak cell delay variation was recorded for each of the handover delays and different bandwidth overheads and can be seen in Figure 2-2.



**Figure 2-2 Peak cell delay variation after connection handoff**

This is without any flow control on the received cell stream, the graph shows there is a considerable cell delay variation caused by the handoff. The amount of variation is reduced if the handover buffer is cleared quickly once switching is complete. The delay variation can also be reduced with a flow control buffer at the receiver, while this does add a slight delay it has been shown to improve the subjective quality of the media [9]. The delay variations with the flow control buffering can be seen in Figure 2-3.



**Figure 2-3 Peak cell delay variations with flow control**

While these results are not ideal they show that using flow control would improve the quality of some ATM services. If a more advanced flow control mechanism was implemented a clearer and more consistent result would be obtained. The loading of the flow control buffer can be seen in Table 2.2. It shows that the important factor in the degree of queue build up is the handover time rather than the increased transmission rates while purging the switch buffers.

BW Overhead	Queue size 25ms HO	Queue size 50ms HO	Queue size 125ms HO
10 %	24	47	88
50 %	24	30	64
70 %	27	34	75

100 %	29	59	108
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**Table 2.2 Flow control queue sizes various handover delays and channel bandwidth overheads**

The results clearly show how the various constraints experienced during a connection handoff affect the handover performance and the effects they have on the other performance measures. Depending on the service type different performance measures would be important and a handoff could be executed based on some of these constraints to provide suitable QoS performance.

### 3 Conclusions and Further Work

In this paper a simple backward handover method is proposed and evaluated for a CBR wireless ATM connection. The Opnet simulation tool was used to model a WATM system and measurements were gathered to assess the quality of the handoffs that were carried out. The primary mechanism affecting the quality of the handoff is the time taken to switch the ATM connections to the new radio access point. This has a direct effect on the queue sizes generated during handover and also affects the amount of delay incurred and the delay variation. It was also shown that the greater the amount of bandwidth available in the new radio cell the faster the buffers could be emptied. This is important as it reduces delay variation and delay and allows a higher frequency of handovers to be carried out. In the case of the flow control buffer at the receiver the effect of purging the handover buffers was negligible but again the over all time taken for the handoff was a factor in the amount of loading experienced. This is not a problem as long as the generated queues do not overload the buffer, which would cause cell losses and misordering.

Measurements obtained using a variable rate 5GHz QPSK modem were also included in the simulation model allowing some estimation of the cell losses that might occur. This allowed for cell retransmission rates to be included in the model and when handoff occurred provided a figure for any cells that would require forwarding to the new access point. This model has shown a number of performance measures for assessing the quality of a WATM handoff. The handoff architecture is also simple enough to be easily implemented as a mobility extension and flexible enough to cope with a number of different scenarios.

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